4.0 V&V STATUS AND USAGE HISTORY

This portion of ASP I summarizes applications in which ESAMS has been employed, and the extent to which those applications have been supported by documented V&V. Details of the assessment procedures for V&V Status and Usage History can be found in the *SMART Accreditation Support Framework* [1], Section 2.3.

ESAMS has a large number of users with a wide variety of applications. The Users Group Points of Contact (POCs) Listing in Appendix C includes 49 individual entries from over 40 different government organizations and commercial firms doing government business. A breakdown of ESAMS users by DoD Service is found in TABLE 4.0-1. The user of ESAMS seeking information to support accreditation should perhaps realize some confidence in the model due to its use by this diverse user group.

TABLE 4.0-1. ESAMS Users by Category.

User Category	Number
Air Force	11
Army	5
Navy	4
Commercial Firms	22
Other	7
TOTAL	49

In 1992, on behalf of the SMART Project office, an independent verification agent (IVA) sent a questionnaire to the user communities seeking information about the use and V&V of the SMART Project models (ALARM, ESAMS, and RADGUNS). This survey was carried out, in part, because of the lack of formal V&V records. For ESAMS, only 55 users responded out of 354 questionnaires sent. TABLE 4.0-2. summarizes the results by question.

TABLE 4.0-2. ESAMS Users Group Survey Results.

Brief Form of Question	YES Responses
Perform any V&V analysis?	21
Accredited for a specific project?	9
Results compared with other models?	21
Results compared with test data?	9
Problems, errors, or weaknesses?	32
Obtained Software Design Document?	2
Obtained Software Development Plan?	3
Developed in-house documentation?	10

Many respondents provided comments beyond the questions. In addition, the survey was followed up with telephone calls to some of the respondents. This additional information is summarized in Table 4.0-3 below. A narrative summary is provided in subsection 4.2.

TABLE 4.0-3. Specific Results of Survey and Follow-up.

Organization/Firm POC	ESAMS Version	Results Compared with Test Data	Results Compared with Other Models	Problems Found
SURVIAC Steven Mascarella, Linda Hamilton (513) 429-9509	1.7, 2.6.2	Unknown	Unknown	Y
Sverdrup Technology, Inc. Dave Diaddario, Mary Burleson (904) 833-7600	1.5, 2.5, 2.6.2	N	MS6DOF	Y
Lockheed-Martin Michael Mulhern (817) 935-4058	1.5, 2.5.6	Y	PASTE, TRAP	Y
ASC/XRE Klaus-Peter Bletzinger (513) 255-2821	2.5, 2.6	Y	IMARS, SAMSIM, PASTE	Y
BDM Dr. David Fisher (505) 848-5000	2.6.2	Y	ALARM	Y
Bell Helicopter Textron Terry Gibson (817) 280-5451	1.1, 1.2, 1.4, 1.4.2, 1.5I, 1.5	N	ALAM, IMARS	Y
(Unspecified Agency) William H. Swearengen (404)494-3077	1.7, 2.6.2	Unknown	Unknown	Y
SPARTA, Inc. Oliver Cathey (714) 768-8161	1.5	N	Y	Y
LORAL Infrared & Imaging Systems, Inc. Michael Bulpett (617) 863-3409	1.5, 1.7	Y	N	Y
HQ AFOTEC/SAN Cheryl Black (505) 846-0503	2.0, 2.5, 2.6, 2.6.2	N	IMARS, TEM	Y
LTV Aircraft Division D. M. Reedy (214) 266-8748	1.6	Unknown	Unknown	Y
SAIC Bob Lucas (703) 525-0081	1.5	N	Y	Y
NAWCWPNS Bob Licklider (619)939-4723	1.7	Y	N	Y
USAFAWC/SC Capt. Lawrence McCaskill (904) 882-4600	1.4, 2.6.2	Unknown	Unknown	Y
General Electric Aircraft Engines Keith Campbell (513) 243-1662	Unknown	N	N	Y

TABLE 4.0-3. Specific Results of Survey and Follow-up. (Contd.)

Organization/Firm POC	ESAMS Version	Results Compared with Test Data	Results Compared with Other Models	Problems Found
USA VAL (WSMR, New Mexico) Greg Marez, Timothy Fahey (505) 678-2967	1.4, 1.5, 1.7	N	IMARS, DISAMS	Y
Office of Naval Intelligence, DI321 Ed Coulter (301) 763-1131	1.4, 2.6	N	N	Y
ASC/XRYM (Eglin AFB) Terry Atkinson (904) 882-9417	1.4, 1.5, 2.5, 2.6.2	Unknown	Unknown	Y
Naval Surface Warfare Center Ms. G. Russel, Mr. N. Talurico (703) 663-4248	1.7	Unknown	IMARS	Unknown
(Unspecified Agency) Capt. R. J. Morris (703) 692-3444	Unknown	N	Y	Unknown
AFEC/SAT Capt. Tom McNeil (512) 977-2391	2.6.2	N	N	Unknown
Naval Air Warfare Center, Aircraft Division Jim Persechino, June Dirany (215) 441-2806/3074	1.5, 1.7	Unknown	Unknown	Y
Litton ATD Gregory Bernard (408) 365-4811	1.5	N	MSEG	Y
Lockheed-Martin Lawrence Hicks (404) 494-8792	1.7	N	Lockheed FMS	Unknown
USSTRATCOM Capt. Tim Swett (402) 294-4584	2.5.6	Y	SAMPk, IMARS	Y
Lockheed-Martin Larry Ost (818) 847-8005	1.6, 2.5.6β	N	LSAMS	Y
Service Engineering Robert Strausser (410) 273-7722	1.6	Unknown	Unknown	Y
McDonnel Aircraft Co. John Lonigro (314) 233-6488	2.5.6	Unknown	Unknown	Y
NAIC/TAIV Mark Brunn (513) 257-3255	1.4.2, 1.5, 1.7, 2.0, 2.5, 2.6.2	N	SIMAL	Y
ASI Gregory Born (619) 375-1442	2.5, 2.6.2, 2.6.3β, 2.7	Y	ALARM	Y

4.1 V&V STATUS

There is a long history of organizations using ESAMS for various studies and analyses, and there has been some V&V work done with the model; however, there is not much formal documentation describing that work. The paragraphs that follow identify the most prominent of those efforts. Note that many of the projects described below are not classical V&V efforts. Rather, they are studies which involved comparison of ESAMS results with field test data and/or output from other models. Because of these comparisons, the studies are categorized as V&V efforts.

1. The SMART Project is currently sponsoring documentation, verification, and validation of the functional algorithms used to model RF sensors and missile flyout in ESAMS. These efforts are described more fully in ASPs II and III.

2. As part of its configuration management of ESAMS, SURVIAC periodically performs face validation testing of new versions of the model. Results of this testing are presented at the quarterly ESAMS Users Group meeting.

3. Massachusetts Institute of Technology, Lincoln Laboratory, Niall Duffy: Simple multipath for command-guided SAMS is being evaluated in ESAMS 2.6.3. Preliminary results indicate over-prediction of command guidance capability. Future work includes continuing multipath model investigation and other aspects of command guidance and seeker variants.

4. U.S. Army Materiel Systems Analysis Activity, Everett Reich: Version 2.6.2 was used in a study of factors affecting threat acquisition of helicopters due to flight tactics. Mr. Reich believes that ESAMS displays poor performance against low-altitude targets and its endgame produces invalid results.

5. Lockheed, Mike Mulhern: The endgame in version 2.6.2 is under test; numerous errors have been found.

6. Booz-Allen & Hamilton (SURVIAC), Steven Mascarella and Linda Hamilton, (513) 429-9509: Versions 1.7 and 2.6.2 were used in an accreditation effort for a Naval SAMs program. The study resulted in over 200 error reports.

7. Sverdrup Technology Inc., Dave Diaddario and Mary Burleson, (904) 833-7600: Versions 1.5, 2.5, and 2.6.2 have been used to support the SIMVAL program, for which SvT is the contractor. SIMVAL generates Acquisition Validation Reports (AVRs), which describe ESAMS on a system-by-system basis and discuss differences between the model and currently assessed threat intelligence. The ESAMS code is examined to formulate the implied algorithms; these algorithms are usually not described in the developer's published user's, programmer's, and analyst's manuals. The algorithms are assessed for validity, and simulated parameter characteristics are evaluated by comparing with validated parameters. Mr. Mark Brunn at FASTC, (513) 257-3255, is the POC for acquiring AVRs.

   For ESAMS Version 1.5, SvT performed missile flyout data collections to examine engagement characteristics, and system and subsystem testing to examine the model's aerodynamic properties and airframe stability. SvT modified (and tested) guidance and control routines, aerodynamic data, and radar data to reflect changes in the threat intelligence baseline. After ESAMS

was modified, results were compared to an in-house developed, 6-DOF model called MS6DOF.

For ESAMS versions 2.5 and 2.6, SvT validated the SA-10, SA-11, and SA-12 radar models, concluding with the generation of AVRs. These validations examined differences between the accepted threat radar parameters and model code values. Based on such differences, assessments were made regarding the impact each difference has on the validity of the simulation. SvT modified version 2.5 to implement a Kalman tracker and use of actual antenna pattern data to generate antenna responses.

8. BDM Inc., Dr. David Fisher, (505) 848-5000: Version 2.6.2 was used in a clutter study that compared ESAMS results with ALARM results and with FLEXAR Clutter Studies data published by Lincoln Laboratory. In Dr. Fisher's opinion, the update rate and random draw characteristics used in the ESAMS clutter routine may not be analytically sound. Further information may be found in the GRACE Functional Acceptance Test published by AFOTEC/SAN.

9. Unspecified Agency, William H. Swearengen, (404) 494-3077: Versions 1.7 and 2.6.2 were used in a study involving "some" V&V activity. Inputs, code, and algorithm errors or problems were found.

10. HQ AFOTEC/SAN, Cheryl Black, (505) 846-0503: Versions 2.0, 2.5, 2.6, 2.6.2 were used in a study comparing ESAMS results with IMARS and TEM results. Inputs, code, and algorithm errors or problems were found.

11. USAFAWC/SC, Capt. Lawrence McCaskill, (904) 882-4600: Versions 1.4 and 2.6.2 were used in a classified study. Input errors or problems were found; version 1.4 outputs were determined to be inaccurate.

12. ASC/XRYM (Eglin AFB), Terry Atkinson, (904) 882-9417: Versions 1.4, 1.5, 2.5, and 2.6.2 were used in an unspecified study. Inputs and code errors or problems were found.

13. AFEWC/SAT, Capt. Tom McNeil, (512) 977-2391: Version 2.6.2 was used to compare ESAMS runs at AFEWC/SAT and AFSAA/SAG; the inputs were identical so that the outputs could be compared to ensure identical model operation at both sites.

14. NAIC/TAIV, Mark Brunn, (513) 257-3255: Versions 1.4.2, 1.5, 1.7, 2.0, 2.5, 2.6.2 were used in comparsions of ESAMS and SIMVAL models. Inputs and code errors or problems were found. Acquisition Validation Reports were published.

15. ASC/XRE, Klaus-Peter Bletzinger, (513) 255-2821: Versions 2.5 and 2.6 were used in a study comparing ESAMS results with values generated by the IMARS, SAMSIM, and PASTE models, as well as with test data (SAR classification). "Numerous" problems or errors were found, many of which were attributed to outdated intelligence data.

16. Office of Naval Intelligence, DI321, Ed Coulter and Les Kushner (301) 763-1131: Versions 1.4 and 2.6 were used in an analysis of the implementation of Naval SAM systems in ESAMS. As a naval intelligence organization, ONI incorporated the latest Naval intelligence estimates into ESAMS version 1.4 to

create the N-SAMS model. According to Mr. Kushner, no documented verification activities occurred. Versions 1.4, 2.6, and NSAMS 1.4 were used in an accreditation effort for the UAV joint program offices. Code and algorithm errors or problems were found.

17. Lockheed-Martin, Michael Mulhern, (817) 935-4058 and Robert Fowler, (817) 935-4057: Versions 1.5 and 2.5.6 were used in an accreditation effort involving F-22 vulnerability studies. ESAMS results were compared with PASTE and TRAP model results, as well as with test data. Inputs and code errors or problems were found.

18. USSTRATCOM, Capt. Jon Davis, (402) 294-4584: Version 2.5.6 was used in a comparison of ESAMS, SAMPk and IMARS models. Results were also compared with test data. Inputs and code errors or problems were found.

19. Lockheed-Martin, Larry Ost, (818) 847-8005: Versions 1.6 and 2.5.6 beta were used in a comparison of ESAMS results with those generated by an in-house SAM model called LSAMS (Lockheed SAMS). Code, algorithm, and other errors or problems were found.

20. McDonnell Aircraft Co., John Lonigro, (314) 233-6488: Version 2.5.6 was used in an unspecified study. Code problems or errors were found.

21. LORAL Infrared and Imaging Systems Inc., Michael Bulpett, (617) 863-3409: Versions 1.5 and 1.7 were used in a study that compared ESAMS results with static and live field test data. Inputs and code errors or problems were found, including outdated missile and radar data, and the absence of newer systems in the model.

22. NAWCWPNS, Bob Licklider, (619) 939-4723: Version 1.7 was used in a study comparing ESAMS results with test data. Algorithm errors or problems were found.

23. USA VAL (WSMR, New Mexico), Greg Marez and Timothy Fahey, (505) 678-2967: Versions 1.4, 1.5, and 1.7 were used to compare ESAMS results with IMARS and DISAMS. Code errors or problems were found.

24. Naval Surface Warfare Center, Ms. G. Russel and Mr. N. Talurico, (703) 663-4248: Version 1.7 was used in an accreditation effort for an unspecified program, in which ESAMS results were compared with IMARS results. Additionally, Ms. Russell uses ESAMS to generate Pk look-up tables for SAM sites for the Cruise Missile Project Office.

25. Naval Air Warfare Center, Aircraft Division, Jim Persechino and June Dirany, (215) 441-2806/3074: Versions 1.5 and 1.7 were used in an unspecified study. Inputs and code errors or problems were found.

26. Lockheed-Martin, Lawrence Hicks, (404) 494-8792: Version 1.7 was used in a comparison of ESAMS and the Lockheed FMS (Full Mission Simulator) real-time SAM model. This real-time model is different from the non-real-time, in-house Lockheed model called LSAMS.

27. Service Engineering, Robert Strausser, (410) 273-7722: Version 1.6 was used in an unspecified study. Inputs and code errors or problems were found.

28. LTV Aircraft Division, D.M. Reedy, (214) 266-8748: Version 1.6 was used in an accreditation effort for a classified program. Inputs and code errors or problems were found.

29. Bell Helicopter Textron, Terry Gibson, (817) 280-5451: Versions 1.1, 1.2, 1.4, 1.4.2, 1.5I, and 1.5 were used in a study comparing detection ranges in ESAMS, ALARM and IMARS. Code, algorithm, and documentation errors or problems were found.

30. SPARTA Inc., Oliver Cathey, (714) 768-8161: Version 1.5 was used to calibrate another model. Unspecified errors or problems were found.

31. SAIC, Bob Lucas, (703) 525-0081: Version 1.5 was used in a study comparing ESAMS results with those generated by other models and with DIA report data. Serious errors or problems were found with Long Range SAM use.

32. Litton ATD, Gregory Bernard, (408) 365-4811: Version 1.5 was used to compare ESAMS results with those from an in-house, scenario-generation model called MSEG. Altitude vs. Pk errors or problems were found.

33. General Electric Aircraft Engines, Keith Campbell, (513) 243-1662: An unspecified version was used during IR&D activity. Code errors or problems were found. Mr. Campbell referenced a more experienced GE user named Mark Feller; Mr. Feller had no verification-related information.

34. ASI, Gregory Born, (619) 375-1442: Versions 2.5, 2.6.2, and 2.6.3b were used for several Air Force sponsored studies at RAND. Detailed verification of ESAMS clutter modeling and comparisons to ALARM clutter algorithms were performed. Additional comparisons to exploitation and hardware simulators have also been performed. Some code and input discrepancies were found.

35. Northrop-Grumman, Joe Wieczorek, (847) 259-9600: Version 2.6.3 was used to compare ESAMS ECM effectiveness for the AN/ALQ-135 with hardware-in-the-loop test data.

36. SAIC, Paul Hannen, (513) 429-6518: Version 2.6.3 was used to compare with a hybrid hardware-in-the-loop and digital simulation.

37. SIMVAL efforts described below may have included some V&V of ESAMS. As the releasing authority grants permission for distribution to SMART Project contractors, any V&V activities included will be reported in updates of the ESAMS ASPs.

4.1.1 NAIC Validation (SIMVAL)

The National Air Intelligence Center (NAIC) reports provide a critique of the ESAMS code and data. Sensor and missile segments are reviewed in the respective documents. The efforts include checkout of the following elements, where, for purposes of illustration, the sensor is taken to be the missile fire control radar and seeker system:

1. Radar Missile
2. Antenna Free Airframe Response
3. Transmitter Damped Airframe Response
4. Receiver Missile Seeker/Guidance Computer Response
5. Signal Processing Computer Response

6. Tracking Servos Total Closed Loop Response
7. Gimbal Servo Flyout Comparisons

The NAIC reports contain both conclusions and recommendations. The conclusions usually quantify how well the simulation represents the system. The recommendations identify corrections that would make the simulation more representative of the real-world system.

A problem that has been present over the years is that the developer has not necessarily had access to the material that NAIC personnel use to evaluate the model. Thus, while the developer may have faithfully modeled the system specified in the approved reference document, NAIC may be gearing the evaluation to other information. A potential result is that substantial changes to ESAMS will be recommended.

SIMVAL reports include the following ESAMS-related work:

1. *ESAMS-4 AVR (U)*, May 1989 (S/NF/WN) [3].
2. *ESAMS-6 Missile Version 1.5 Update Acquisition Validation Report (AVR) (U)*, October 1990 (S/NF/WN) [4].
3. *ESAMS-8 AVR (U)*, February 1990 (S/NF/WN) [5].
4. *ESAMS-11 Version 1.5 Update AVR (U)*, April 1990 (S/NF/WN) [6].
5. *ESAMS 2.5 1000/1200 AVR (U)*, April 1992 (S/NF/WN) [8].
6. *ESAMS 2.5 SA-11 AVR (U)*, August 1991 (S/NF/WN) [9].

4.1.2 Clutter Validation

ESAMS uses clutter reflectivity based on Georgia Institute of Technology and Massachusetts Institute of Technology's Lincoln Laboratory data. Both of these sources use methodology developed from field test operations. The Lincoln Laboratory methodology views clutter reflectivity as a function of radar depression angle and terrain characteristics. Georgia Tech methodology is based on grazing angle, rather than depression angle.

While differences exist, both of the methodologies are founded on sound practices and procedures. Although the impacts of clutter, multipath, and diffraction may never be quantified as fully as desired, the clutter reflectivity algorithms used in ESAMS have been validated to a substantial degree. Reports documenting these efforts include the following:

1. *TAC ZINGER Clutter and Multipath Models for Track-while-Scan Systems*, Georgia Tech/EES Project A-2460, Steven P. Stuk, Georgia Institute of Technology Engineering Experiment Station, November 1980 [18].
2. *Low Angle X-Band Radar Ground Clutter Spatial Amplitude Statistics (U)*, Project Report CMT-83, J. B. Billingsley and P.C. Crocheterie, Lincoln Laboratory, Massachusetts Institute of Technology, August 5, 1986 (SECRET) [19].
3. *Multifrequency Measurements of Low Angle Radar Ground Clutter at 42 Sites (U)*, Project Report CMT-87, J. B. Billingsley and P.C. Crocheterie, Lincoln

Laboratory, Massachusetts Institute of Technology, November 10, 1987 (SECRET) [20].

4. *Ground Clutter Measurements for Air Defense Radar (U)*, Technical Report 786, J. B. Billingsley and P.C. Crocheterie, Lincoln Laboratory, Massachusetts Institute of Technology, November 10, 1987 (SECRET) [21].

4.2 USAGE HISTORY

ESAMS is a second-generation follow-on to the TAC ZINGER models that were constructed by the AFSAA in the 1970s. The TAC ZINGER series was widely used in survivability analyses, and three of the missile simulations in this series were selected to portray the Soviet Missile Threat in the Joint Test TASVAL. This field test addressed the issue of A-10 and attack helicopter survivability in a close air, support environment. The TAC ZINGER models were later employed in the Electronic Warfare/Close Air Support (EW/CAS) field test, that addressed the issue of electronic warfare effectiveness in tactical scenarios.

The ESAMS series evolved in the 1980s, with emphasis being placed on expanded sensor modeling. ESAMS has maintained a wide user base while upgrading model performance. Presently, the Soviet SA-2 through SA-16 are modeled, and four of the Soviet Naval SAMs are simulated.

Some recent studies involving ESAMS are presented below:

1. AFSAA/SAG, Maj. Jim Herring: Maj. Herring is currently using ESAMS 2.6.3b to generate SAM engagement envelopes for the Joint TacAir Electronic Warfare Study (JTAEWS). Results of this study will be briefed at upcoming ESAMS Users Group meetings.
2. USSTRATCOM, Capt. Tim Swett: ECM and responses to the ECM are being added to ESAMS 2.6.3 to accomodate requirements for the B-1B and B-52 aircraft defensive system functions.
3. USSTRATCOM/J534, Capt. Jon Davis: In a study of ESAMS 2.6.3 ECM, Capt. Davis ran the model using a very large target in both a dry and ECM environment. He eventually plans to compare the ESAMS results with range test data. Capt. Davis' preliminary results show ECM is very effective; however, the results are subject to interpretation because the study involved no ECCM. He has also noted problems due to the absence of automatic ECCM and the lack of documentation.
4. McDonnell Douglas Aerospace Company, Nick Talarico: ESAMS 2.6.2 has been used in the threat analysis module of MDAC's Aircraft Mission Planner. MDAC has conducted studies using ESAMS with modified multipath and clutter algorithms to include random terrain characteristics.
5. ASC/XRE, Jordan Wescott: At a recent Users Group meeting, Mr. Wescott presented a classified briefing that showed the results of a comparison of the ESAMS 2.6.2 ASC/XRE code and the ESAMS 2.6.2 street code for the SA-8 and SA-11 missiles. He presented envelopes for straight and level, ECM, and 3- and 6-GEE maneuvering flight paths.

6. Northrop, Joe Wiecozorek: At a recent Users Group meeting, Mr. Wiecozorek presented results of an F-15E study using the ALQ 135 jammer against various RF missiles. He found that the ECM techniques were effective against these missiles.

4.3 IMPLICATIONS FOR MODEL USE

ESAMS has been used in many DoD studies as one of the primary tools for analyzing surface-to-air missile performance. It has been incorporated in the ACES/Phoenix model execution environment designed and built by AFOTEC and STRATCOM to support operational testing of the B-2A "stealth" bomber. The potential user can realize some confidence in ESAMS from its extensive past use.

As one of three pilot models in the SMART Project, as well as its inclusion in the NAIC SIMVAL program, ESAMS V&V efforts have been considerable in recent years. ESAMS is a mature model with a large number of users, many of whom have looked at details of the model's implementation. While no model is perfect, the larger the number of experienced users reviewing the code, the better and more reliable that code will become. The analyst attempting to accredit ESAMS for a new study should have confidence in the accuracy of the code that has been formally assessed as long as current CM processes remain viable.

With the development of Accreditation Support Packages, accreditation efforts by new users can focus on the specific applications needed by the accrediting organization. Because ASP I contains this summary of previous VV&A efforts, along with results and Points of Contact, an analyst trying to accredit ESAMS for a future study has at least some information to support such an effort. ASP-II and ASP-III provide detailed V&V results for ESAMS.